No. 9.

6913

DEPENDABLE CONCRETE

HYDRATED LIME

and its effect on

WORKABILITY · SEGREGATION
UNIFORMITY · STRENGTH
PERMEABILITY

6913

HYDRATED LIME BUREAU
of the
NATIONAL LIME MANUFACTURERS ASSOCIATION
ARROTT BUILDING
PITTSBURGH, PENNA.

BULLETIN A-2

Requisites of Dependable Concrete

Should be composed of materials of suitable quality and gradation.

Should be thoroughly mixed.

Should be plastic enough to work freely in the forms and perfectly embed reinforcing steel.

Should have a uniform distribution of the cement, sand and stone in the hardened mass.

Should be homogeneous and free from honeycombing.

Should be watertight.

This list of characteristics of dependable concrete does not present any feature that is new to those experienced in concrete construction. Concrete possessing these properties has been produced in the laboratory and could be produced in the field under ideal conditions of materials, labor and supervision; but practical limitations and exigencies of present day construction practice make the attainment of these ideal conditions a rare occurrence.

On page 54, Technologic Paper No. 58, U. S. Bureau of Standards, is found the following:

"During the past few years it has become the practice on large concrete construction jobs to mix the concrete at a central point and convey the mixtures to the various parts of the structure by means of a tower and chutes. That this method has proven very economical for the contractor is shown by its almost universal use on large work; but the quality of the concrete in place has apparently been a secondary consideration. It is possible that good quality concrete is obtained when the materials are handled in this manner, but it is probable that the strength obtained is very much less than what it should be for the same materials properly mixed to a drier consistency."

"Speed" is the watchword of present day construction. To maintain speed, a quick flowing concrete is a desirable factor and usually employed. An excessive amount of mixing water is often used to bring about the desired flowing property of the concrete. It is well known that excessive mixing water is harmful. Separation of the aggregate follows, and separation means stratified layers of material or pockets of stone and mortar. Honeycombing is largely an outward telltale of this undesirable condition. The excess water itself occupies space and lends porosity to the concrete. Surely these conditions warrant the most serious attention of every engineer.

To correct some of the known tendencies of concrete construction, prominent engineers, after intensive study and extensive experimental work, determined to what extent a material having characteristics peculiar to hydrated lime can be employed in mixing and placing concrete in order to insure the all-important properties of good concrete—uniformity, density and impermeability. They found that the addition of hydrated lime introduced definite characteristics which are of marked advantage in producing concrete of superior quality.

The following pages are written for the information of those interested in concrete construction and not already familiar with the benefits to be derived from the use of hydrated lime in concrete.

Results Gained by the Addition of Small Percentages of Hydrated Lime to Concrete Mixtures

1. Increases the slipperiness of the concrete so that it flows freely without the use of excess water.

2. Minimizes the tendency of sand and stone to separate from the cement, preventing the formation of stone pockets and honeycombing.

3. Produces a freer moving concrete in the forms, making spading easier and resulting in more nearly perfect exterior surfaces and better embedment of reinforcing steel.

4. Results in homogeneous concrete of maximum strength.

5. Renders the concrete less porous and more nearly impermeable, minimizing alternate expansion and contraction due to moisture changes.

6. Acts as added protection against corrosion of reinforcing steel.

Plastic Properties

During the time of mixing and placing concrete and up to the time it begins to harden, concrete may be considered as a plastic material. The term plastic as used in reference to concrete may be defined as that property which permits the homogeneous material to be cast or molded into shape. It may be said that the plastic materials differ from other materials of construction in that their strength and structural integrity depend to a much greater extent upon the skill of the user than upon that of the manufacturer. For example, Portland cement is made by manufacturers to pass a standard specification, and if cement of this character is used it may be depended upon to perform its particular function; so it may be stated that the quality of concrete is much more dependent upon the quality of the stone, sand and workmanship than upon the cement. Assuming that the sand and stone are of acceptable quality, this discussion will be confined entirely to the element of workmanship.

From the previous definition of plasticity, it will be seen that any greater degree of plasticity which may be introduced into concrete will be an assurance of better workmanship. Together with workmanship, however, modern methods of construction demand speed, so that concrete having the qualifications necessary to cause it to flow freely is required. To this end excessive amounts of mixing water are often used, but most certainly at the expense of good, uniform concrete; therefore, any material that will improve the plastic property of the wet mixture without decreasing its ultimate strength must be recognized as advantageous.

Hydrated lime is well known for its high plastic value, and is the most plastic of any building material. An example of its high plastic value is today found on many jobs of brick masonry where the brick mason desires to use hydrated lime with cement mortar "to make it work freely under the trowel." Here its value is closely identical to that as claimed in concrete. By adding small percentages of hydrated lime (5% to 15%) by weight of cement, concrete has been found to have its plastic properties increased, so much so that it flows freely down the longest chute without the development of segregation. The concrete acquires a slipperiness that is a guarantee to the engineer against the need of excess water. By eliminating the cause, the surest cure is being effected.

A very interesting example of the effectiveness of hydrated lime in overcoming the low flowing value of a concrete is related by Robert S. Edwards, Engineer, Portland, Oregon.

"During the fall of 1912 and the winter of 1913 the Stone & Webster Engineering Corporation constructed a large concrete dam located on the White Salmon River, about seventy miles from Portland, Oregon. Our concern was retained by Stone & Webster and the Northwestern Electric Company, for whom the dam was built, to inspect the material used in the concrete work. A thorough investigation was made to determine the advisability of manufacturing the sand which was to be used in this work, and it was finally decided to erect a large crushing and sand manufacturing plant and secure both fine and coarse aggregate for the concrete in this manner. The sand was made by crushing a basaltic rock secured from the crusher located on the bank of the stream at an elevation of six hundred feet above the river bed. The fine crushed rock was screened through a ¼" mesh, and the fine and coarse crushed rock was in bins just above the mixing plant, from which point eighty per cent of the concrete was poured down a spout or chute four hundred feet in length to the dam site below. From numerous test results it was decided to use ten per cent of hydrated lime throughout the concrete, the mixture being 1-3-6. It is more difficult to secure easy working concrete when using crushed rock as the coarse aggregate than when using gravel, this being due to the angularity of the crushed rock. In this case we not only had to contend with the crushed coarse aggregate, but sand sized material was also angular, in fact to such an extent that the concrete mixture would not flow down the steel lined chutes without mechanical aid. By the addition of ten per cent of hydrated lime or approximately forty pounds of hydrated lime per yard of 1-3-6 concrete, we literally transformed the physical appearance of the concrete as seen in the chutes. The concrete would leave the mixers, pass into the chutes and then onward without the slightest separation of the aggregate and would finally arrive at the dam in a perfectly homogeneous mass, where it would flatten out to a level with but little shoveling and spading in the forms. The hydrated lime, together with proper mixing, had given the concrete sufficient plasticity to destroy the excess friction caused by the angular condition of the fine and coarse aggregate, and formed a smooth flowing, uninterrupted stream of concrete, to be deposited in its final resting place in the dam."

Dam, White Salmon River, Washington. *10% hydrated lime used in all concrete.*
This dam was finished early in 1913 and is now completing its third year of satisfactory service.

Another instance where hydrated lime acted as mechanical aid for chuting and placing concrete is cited in the following letter from the Vang Construction Company, Cumberland, Md., contractors on the new Market street bridge, Chattanooga, Tenn.:

"Due to the extreme distance it has been necessary for us to spout the concrete, we have used small percentages of hydrate in order to eliminate separation of materials and 'lubricate the spouts.' Our towers are approximately two hundred feet high and we are now spouting a distance of about four hundred and sixty feet from each tower. We also find that the hydrate gives a much denser concrete, especially in our balustrade work."

Maximum Strength

Undoubtedly the most important factor determining ultimate strength of concrete is the uniform distribution of cement, sand and stone throughout the mixture. In resorting to excessive quantities of water to make concrete flow, the possibility of obtaining maximum strength is diminished. Upon turning the mixture into the chute, the excess water, together with the finest particles of cement, immediately passes down the incline, followed by a mixture of cement and sand, and this in turn is followed by the slower moving and angular stone, a large portion of which has been washed clean of the mortar coating. In the forms there is found a thin mixture of water, cement and sand, and the stone, by its specific gravity, passes through this thin mixture and settles in a layer at the bottom.

By eliminating the cause of such undesirable concrete by the use of hydrated lime, there is automatically obtained a concrete that rests in the forms with the stone more uniformly distributed throughout an unctuous mixture of cement and sand.

On page 89 of Technologic Paper No. 58, issued by the U. S. Bureau of Standards, is found the following: "The quantity of water added to the mixture in preparing concrete affects materially the compressive strength at all ages. With the proper quantity of water the strength may be several hundred per cent greater than that obtained with a large excess of water."

Again on page 91 under "Conclusions" is found: "The compressive strength of concrete may be reduced by the use of an excess of water in mixing to a fractional part of that which it should attain with the same materials. **Too much emphasis can not be**

placed upon the injurious effect of the use of excessive quantities of water in mixing concrete."

It is very well known that sand and stone containing low percentages of water are more compact than a dry sand and stone. On the other hand, if water over a certain low percentage is added, it acts in the opposite manner and separation follows. Hydrated lime is of a colloidal nature and has the power of absorbing larger quantities of water than Portland cement, and this fact gives it added advantage. Hydrated lime, upon being wetted, loses its granular character and is converted into a homogeneous, unctuous substance, in the manner observed when soaking pulverized gelatine. In this state it holds the water uniformly distributed throughout the mortar paste so that it cannot act as an agent separating particles of the aggregates from each other. This water is available to be taken up by the chemical requirements of the cement in the process of hydration, resulting in a tendency toward maximum strength, and in this respect it must be clear that the finely divided, void filling hydrated lime is essentially an improving agent to concrete as well as a preventive of evils.

Following are a few of the reinforced concrete structures containing small percentages of hydrated lime to promote plasticity and homogeneity:

Bolivar St. Viaduct, Marshall, Tex. (now under construction).

Chouteau Ave. Viaduct, St. Louis, Mo. (now under construction).

Indianapolis & Frankfort R. R. (Vandalia Lines) (now under construction).

Taylor St. Bridge, Fort Wayne, Ind. for Wabash R. R. Company. (now under construction).

U. S. Reclamation Work, Meadow Creek, Wash. (now under construction).

Federal Dyestuffs Co. building, Kingsport, Tenn. (now under construction).

Ford Dam, Delta, Pa. (now under construction).

Whipple Bridge, Dept. of Public Roads, State of Rhode Island. (now under construction).

Watertight Concrete

Hydrated lime has been successfully used as an integral waterproofing agent in such structures as dams, reservoirs, sewers, tanks. tunnels, bridges, etc., by some of the most prominent engineers. That its use as a material for producing watertight concrete is not as generally known as its qualities and the results obtained by its use would merit, is principally due to the fact that up to recently it has never been widely exploited, nor brought to the attention of engineers, architects and contractors in a sufficiently forcible manner to make lasting impression.

Impermeability of concrete is in direct proportion to the density. For two reasons the necessary degree of density is obtained through the judicious use of hydrated lime. First, hydrated lime is a very finely divided material and serves to fill the voids. Second, and probably the more important, is the freer movement natural to a concrete containing hydrated lime. This free movement makes it possible to secure the most dense concrete with the least amount of manual labor.

The U. S. Bureau of Standards states in Technologic Paper No. 3, page 59, that in a test comprising forty waterproofing materials, **hydrated lime proved to be the most efficient.** A few of the large and more important concrete structures that have been made watertight by hydrated lime are given below:

St. Louis Filtration Plant, St. Louis, Mo., between 700 and 800 tons of hydrated lime being used.

Stockton Street Tunnel, San Francisco, Cal., largest span tunnel in the world.

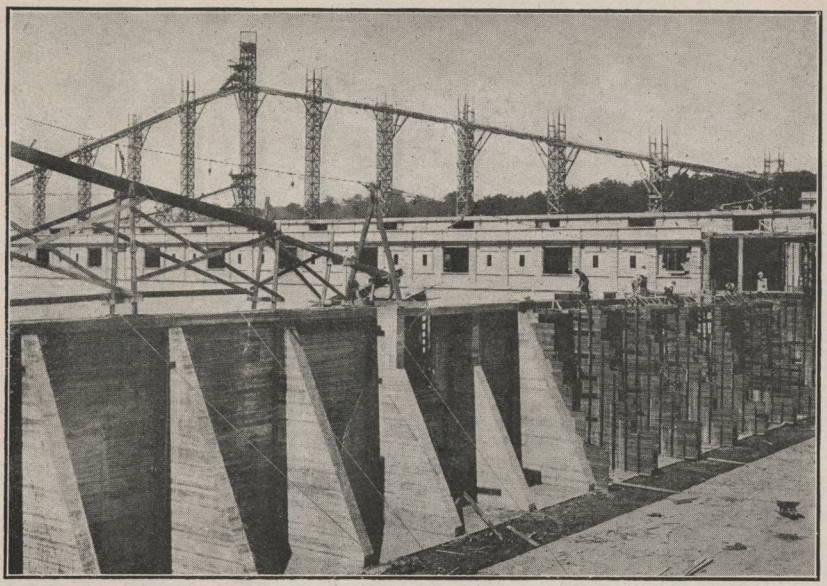
Estacada Dam on the Clackamas River, near Oregon City, Ore. Thirty pounds of hydrated lime used to each cubic yard of concrete.

Stony Brook Sewer, City of Boston, Mass. Twelve per cent addition of hydrated lime by weight of cement.

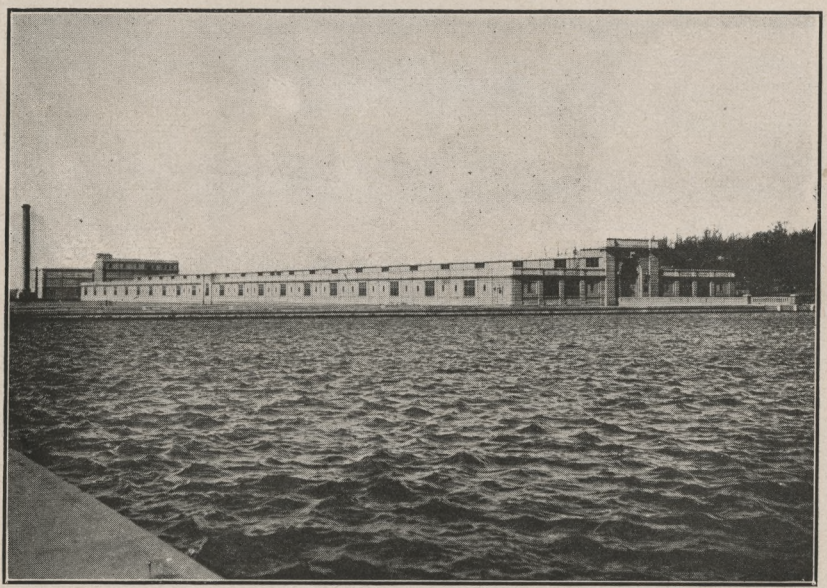
Concrete Reservoir, LaCrosse, Wis., 5,000,000 gallons. Ten per cent of hydrated lime used.

Expansion and Contraction

It has been definitely established that concrete expands and contracts somewhat under the influence of normal changes of temperature, **but volume changes due to alternate wetting and drying are found to be much greater.**



View showing portion of St. Louis Filtration Plant under construction.



View showing same portion of St. Louis Filtration Plant completed.
Over 700 tons of hydrated lime used for making watertight concrete.

It is customary in designing concrete structures exposed to temperature changes to take such conditions into consideration, although the question of movements due to alternate wetting and drying is seldom considered. It is therefore evident that the more important of the two factors controlling volumetric changes receives the lesser consideration.

Water penetrating concrete causes further chemical reaction of the cement and this reaction is accompanied by expansion; upon drying out, contraction follows. This action is repeated each time the concrete is exposed to alternately wet and dry conditions, often breaking the continuity of the concrete. In reinforced concrete structures, where the steel is embedded close to the surface, serious stresses are likely to occur, due to the expansion or contraction of the concrete from change in moisture content, while the steel undergoes no change from the same cause. Thus, from this reasoning, the effect of moisture must be regarded as one of progressive disintegration.

It easily follows then, that permanency of concrete is dependent upon the degree to which the structure is made dense and impervious. Since it has already been shown that hydrated lime is effective in producing watertight concrete, it must also be recognized as a successful method of promoting durability.

A prominent application of hydrated lime demonstrating the correctness of these statements lies in its use in the construction of concrete roads in which the number of transverse cracks have been reduced. A few concrete roads attesting these facts are as follows:

Coleman DuPont Road, Delaware.
Pavements in city of Superior, Wisconsin.
Jericho Road, Kane County, Illinois.
State Highways at Northbridge and Randolph, Massachusetts.
Concrete Roads in Province of Ontario, Canada.

Protection of Reinforcing Steel

As the steel used in reinforced concrete is designed to take certain stresses, it is important to take adequate means of protecting the steel from any action causing corrosion. Serious corrosive action may lead to failure of the structure.

It is generally conceded that reinforcing steel firmly imbedded in dense, impervious concrete will not corrode, as corrosion takes

View showing portion of Jericho Road, Kane County, Illinois.
Monolithic type of concrete road containing 10% hydrated lime

place only in the presence of moisture. It has already been shown in the foregoing that the judicious use of hydrated lime is productive of concrete of the required type, but in addition the lime acts as an added precaution by being of an alkaline nature and, as such, neutralizes any acid which may be present, including carbonic acid.

Efflorescence

Efflorescence is the white substance often seen disfiguring the surfaces of concrete and is generally supposed to be due to the soluble salts in the concrete, dissolved by penetrating water. When the water is drawn from the concrete by evaporation, the salts are deposited on the surface.

Probably the best method of lessening and preventing efflorescence is by making the concrete watertight, since, by keeping water from penetrating through the surface, the salts will not be dissolved. Hydrated lime is proving itself to be a preventive of efflorescence, due, no doubt, to its effectiveness as a watertightening material.

Conclusion

Hydrated lime is not offered in the foregoing pages as a cure-all for the ill-treatment of concrete in present day practice. It must be admitted, however, that concrete is subject to certain known tendencies and an effort has been made to show the effect of small percentages of hydrated lime in partially overcoming the tendencies set forth in the preceding pages. The mechanical influences exercised by hydrated lime are valuable in producing concrete of a more desirable quality.

Cost

As the market price of hydrated lime is low, its use in concrete is economical, so much so as to warrant its use in all classes of concrete construction. Hydrated lime is on sale by nearly all builders supply dealers and costs about one-half cent per pound.

Correct Proportions of Hydrated Lime

The amount of hydrated lime recommended is ten pounds to be added to each bag of cement used in a concrete mixture of 1-2-4 proportions. The amount recommended, however, for use in mixtures leaner in cement than 1-2-4 will change in accordance with

the proportions of the mixtures. For a 1-2½-5 mix twelve pounds is recommended to each bag of cement, and for a 1-3-6 mix fifteen pounds is recommended.

Method of Incorporation

The method of incorporating hydrated lime into a concrete mixture is simple and accurate. An eight quart pail full holds approximately ten pounds of hydrate, and if the supply of hydrated lime is retained in a box at the side of the loading skip, a pailful for every bag of cement can be taken out and added to the dry materials in the skip. Charging the drum and mixing then proceeds in exactly the same manner as usual.

Specifications

Hydrated lime is a recognized standard material of construction and the American Society for Testing Materials has published specifications setting forth the essential requisites of good hydrated lime. Any hydrated lime which meets the requirements of these specifications can be depended upon to produce the results enumerated in these pages.

As a matter of protection, all specifications for hydrated lime should contain the sentence:

"Hydrated lime shall conform to the standard specifications of the American Society for Testing Materials."